

## TWO NEW SPECIES OF *AUREALCAULIS* (OSMUNDACEAE) FROM NORTHWESTERN NEW MEXICO

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**ABSTRACT.**—Two new osmundaceous species, *Aurealcaulis moorei* and *A. bransonii*, are described from the San Juan Basin of northwestern New Mexico. The area from which they were collected is uncertain, but it is presumed they came from the Lower Eocene San Jose Formation near Angel Peak, southeast of Bloomfield, New Mexico. The species are characterized by having a heterogeneous (*A. moorei*) to homogeneous (*A. bransonii*) pith, non- or partial closure of their leaf gaps, exarch protoxylem clusters, formation of their C-shaped leaf traces by fusion of two segments from adjacent xylem strands in their inner cortices, relatively low numbers of traces in their cortices (16–22 in *A. moorei*, 15–19 in *A. bransonii*), roots arising from lateral margins of these segments, sclerenchymatous outer cortex that connects with the sclerotic ring of the petiolar vascular strand, crenate (*A. moorei*) or interrupted (*A. bransonii*) sclerenchyma lining the adaxial concavity of their petiole strands, and leaf bases that may or may not contain one, occasionally two, sclerotic cellular masses in their stipular wings in *A. moorei* and 6–8 more or less aligned masses in *A. bransonii*. They are compared with other osmundaceous taxa, particularly *A. crossii* Tidwell & Parker of Paleocene age. Because of variations in these new species, *Aurealcaulis* Tidwell & Parker is slightly emended to accept species of this genus with heterogeneous or homogeneous piths, protoxylem becoming endarch in the leaf traces, petiolar vascular strands formed by fusion of segments from the xylem strands in the inner cortex, outer cortex, or outside the stem, and the occurrence or nonoccurrence of sclerenchyma in the adaxial concavity of their petiolar vascular strands and in their stipular wings. The paleoecological conditions under which these species of *Aurealcaulis* grew are also considered.

**Key words:** *Aurealcaulis*, *Osmundaceae*, New Mexico, Eocene, San Juan Basin, San Jose Formation.

*Aurealcaulis* Tidwell & Parker (1987) has a rather limited fossil record at present, but with the addition of the two new species described in this report from the San Juan Basin, New Mexico, and a third as yet unreported one from near the Black Hills, South Dakota, it seems to have been an important, albeit small, component of Early Tertiary floras. The genus also appears to have possibly occurred higher in the Tertiary before it became extinct and was more widely distributed than previously known.

The definite age and collection site for the specimens upon which this paper is based are currently unknown. Portions of them were donated first by Mr. Doug Moore of Glendora, California, who assumed they were collected from the Upper Jurassic Morrison Formation in Lisbon Valley of east central Utah (Tidwell et al. 1989). Mr. William Branson of Helper, Utah, from whom Mr. Moore had originally obtained the specimens, corrected this information and stated he had in turn

acquired them from Mr. J. B. Sanchez of San Juan Gems of Cortez, Colorado. An unknown collector had sold them to Mr. Sanchez, and the only information he had was that they were collected near Farmington, New Mexico, and had been purchased with fossil wood preserved as bright yellow jasper. The fossil wood was traced to the Upper Cretaceous Kirtland Shale northwest of Farmington, but the ferns were never found. The ferns, however, are anatomically more advanced than *Aurealcaulis crossii* of Paleocene age and therefore are most likely from the Lower Eocene San Jose Formation, presumably from an area east of Angel Peak, southeast of Bloomfield, New Mexico. Considerable time and money have been spent attempting to locate the site, but the effort as yet has been unsuccessful.

Reports of fossil plants in the stratigraphic units from the Angel Peak region are rather sparse. Numerous fossil vertebrates, however, have been described from the Paleocene

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Nacimiento Formation on the west side of the peak (Wilson 1951, Taylor 1981). Although abundant undescribed fossil woods occur in the San Jose Formation, the only fossil plants previously recorded from the formation in this general area are compressional-impressional material from nearby Santos Peak (Tidwell et al. 1981). This small flora of leaves and leafy shoots consists of 15 species representing ferns, conifers, and flowering plants. The ferns include fragments of the leaves of *Acrostichum hesperium* and specimens of probable *Danaea*.

This report of *Aurealcaulis* species from New Mexico is significant because they are the first permineralized specimens of Osmundaceae and only the second report of osmundaceous fossils from this state. Leaves assignable to *Cladophlebis* sp. and *Osmunda hollicki* Knowlton were previously reported from the Upper Cretaceous Fruitland-Kirkland Formations in the San Juan Basin (Tidwell et al. 1981). Knowlton (1917) described *O. hollicki* from the Upper Cretaceous Vermejo Formation across the border near Wallburg, Colorado, and the senior author collected osmundaceous leaves, but did not report them, from a coal mine in the Paleocene Raton Formation west of Raton, New Mexico.

#### TAXONOMY

*Aurealcaulis* Tidwell & Parker, emended

EMENDED DIAGNOSIS.—Fossil osmundaceous rhizomes, arborescent or erect axes, surrounded by a mantle of leaf bases and adventitious roots; dissected ectophloic siphonostele or ectophloic dictyostele; xylem cylinder 10 or more tracheids thick, high number xylem strands, leaf gaps delayed, high, and wide; pith homogeneous or heterogeneous; cortex differentiated into inner and outer tissues; leaf traces often found in two segments, adaxially curved, protoxylem exarch, fusing and becoming endarch in inner cortex, outer cortex, or outside stem; petioles stipulate; sclerenchyma lining petiolar vascular strands may or may not be present; sclerotic ring homogeneous; stipular wings with or without sclerenchyma; roots diverge from leaf traces in inner cortex.

*Aurealcaulis moorei*, sp. nov.

Figs. 1A-B, 2, 3A

DIAGNOSIS.—Erect or arborescent, stem 14–16 mm in diameter, surrounded by leaf bases and roots; stele 7–8 mm across, dissected ectophloic siphonostele; pith 2–2.5 mm across, heterogeneous; xylem cylinder dissected, 32–36 xylem strands separated by leaf gaps, strands 15–18 tracheids thick radially, gaps lack closure, protoxylem exarch; phloem external; inner cortex 0.7–1 mm wide, parenchymatous; outer cortex homogeneous, 2–3 mm wide, sclerenchymatous; 16–22 leaf traces per transverse section of cortex; departing leaf trace two segments originating from adjacent xylem strands, fused into C-shaped trace in inner cortex; protoxylem becoming endarch, petiolar vascular strand curved, sclerotic tissue adaxially flattened, becoming crenate; sclerotic ring homogeneous, sclerenchymatous; stipular wings may or may not contain one, occasionally two, large, round cellular masses of sclerenchyma in each wing; roots arise from lateral edge of segments of traces in inner cortex.

REPOSITORY.—Brigham Young University 5041 (HOLOTYPE).

LOCALITY.—Uncertain, possibly the eastern slope of Angel Peak, northwestern New Mexico.

HORIZON.—Uncertain, possibly the San Jose Formation.

AGE.—Uncertain, possibly Early Eocene.

ETYMOLOGY.—The specific epithet is for Mr. Doug Moore of Glendora, California, for donating the specimens for this study.

DESCRIPTION.—The specimen (90 mm across  $\times$  85 mm tall) of *A. moorei* consists of a stem surrounded by petiole bases and adventitious roots (Figs. 1A, 2A, 3A). The base of the specimen is composed of roots and distorted leaf bases. A column of parenchyma cells 78–97  $\mu$ m in diameter in the center and a zone of thick-walled sclerotic tissue 6–10 cells wide around its periphery form the heterogeneous pith (Fig. 2F). The diameters of the sclerenchyma cells vary between 85 and 120  $\mu$ m with walls 10  $\mu$ m thick. The sclerenchyma typically projects into the leaf gaps for a short distance. Most of the parenchyma cells in the center of the pith have been destroyed and replaced with mineral matter.

The xylem cylinder is 2–3 mm across and contains 32–36 strands of xylem separated by

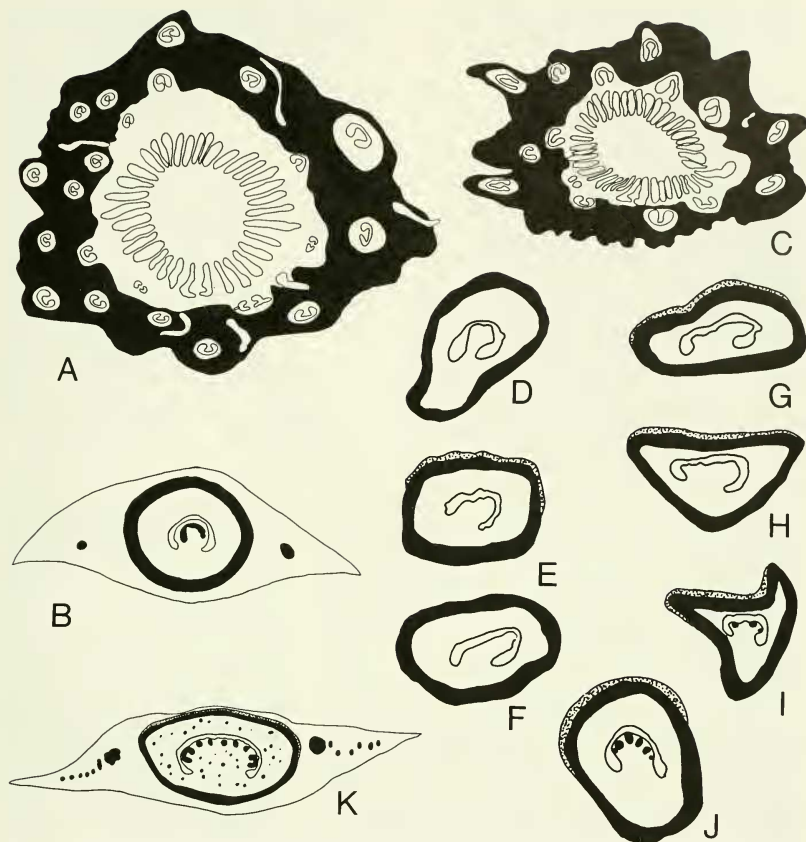
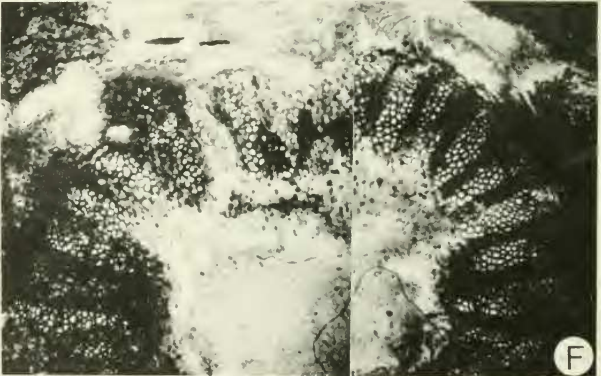
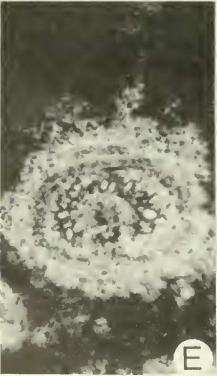
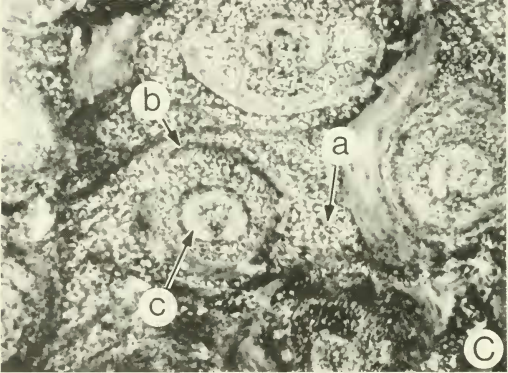
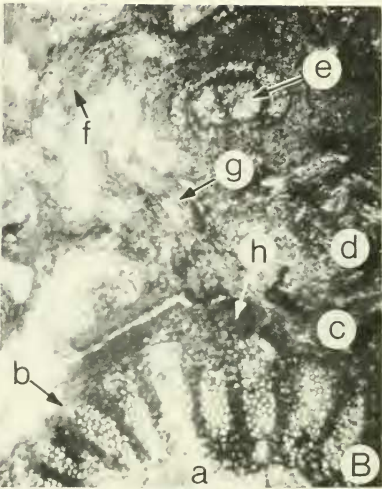
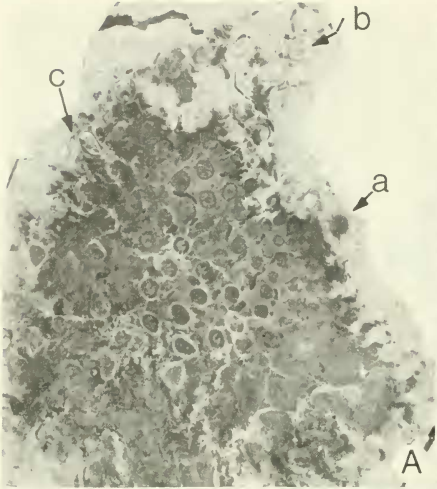


Fig. 1. A–B. *Aurealcaulis moorei* sp. nov. (5041, 1): A, stem, X4; B, petiole with attached stipular wings; note masses of sclerenchyma in each wing, X5; C–K, *Aurealcaulis bransonii* sp. nov. (5042, 1): C, stem X4; D–J, sequence of petioles from stem outward; note heterogeneous sclerotic rings in E, G–J, X5; K, petiole with attached stipular wings illustrating the abundance of sclerenchyma in the petioles and wings, X5. Black = sclerenchyma and sclerotic outer cortex of the stems (all transverse sections).

complete leaf gaps that do not show closure (Figs. 2B, 2F). Thus, the strands are distinct and do not connect with one another at any point. They have a radial thickness of 15–18 tracheids and are 3–6 metaxylem tracheids wide. The latter are 40–120  $\mu\text{m}$  wide by 400–650  $\mu\text{m}$  long and have scalariform pitting in their walls. Protoxylem groups are exarch on the external part of each xylem strand with individual elements that are 19–40  $\mu\text{m}$  in diameter.

A poorly preserved, discontinuous zone of thin-walled cells (1–2 cells wide) between the xylem and phloem represents the xylem sheath. It connects with the parenchyma in the leaf gaps. Cells of the gaps are radially elongated, paralleling the margins of the gap, and are 50–60  $\mu\text{m}$  long and 19–38  $\mu\text{m}$  wide. Sclerotic cells similar to those of the outer pith occur about one-third the length of the gap near the pith, and the radially elongated parenchyma cells occupy the remainder.



Leaf trace development begins when the exarch protoxylem groups on separate, but adjacent, strands face one another and then split off with connecting metaxylem elements, forming two distinct segments (Fig. 2D). These segments fuse and form a single C-shaped trace in the inner cortex (Fig. 2E). The protoxylem groups, one from each segment, become endarch in the trace, eventually dividing into as many as seven protoxylem points in the petiolar vascular strands (Fig. 1B).

Generally, poorly preserved phloem is crushed. The metaphloem appears to be 2–3 cells wide, the cells varying from 19 to 38  $\mu\text{m}$  in diameter. Protophloem is indiscernible.

The endodermis is represented by a line of crushed cells 20  $\mu\text{m}$  wide, filled with dark contents. It is continuous and separates the cortex from the stele.

Parenchymatous tissue of the inner cortex is composed of isodiametric (5–7  $\mu\text{m}$ ) cells near the endodermis and appears as a zone of tangentially elongated cells (30–50  $\mu\text{m}$   $\times$  100–150  $\mu\text{m}$ ) perpendicular to the xylem strands and surrounding the stele. Leaf traces in the inner cortex are surrounded by parenchymatous cortical cells and a thin endodermis as they leave this tissue. Also, prior to the segments fusing and then leaving this tissue, adventitious roots depart from their outer margins, usually from one segment first and then from the opposite one.

Homogeneous, sclerenchymatous tissue (cells 30–60  $\mu\text{m}$   $\times$  180–400  $\mu\text{m}$ ) composing the outer cortex encloses the departing C-shaped leaf traces after the segments have fused. This tissue forms the sclerotic ring around the traces.

At the point of departure, the leaf traces are 1–2 tracheids thick at their centers and 3–4 thick on their flanks (Fig. 2E). Continuous sclerenchyma is present in the adaxial concavities of the traces.

A crushed xylem sheath and phloem, 1–2 cells wide, are abaxial on the xylem of the petiolar vascular strands. A 3-cell-layered

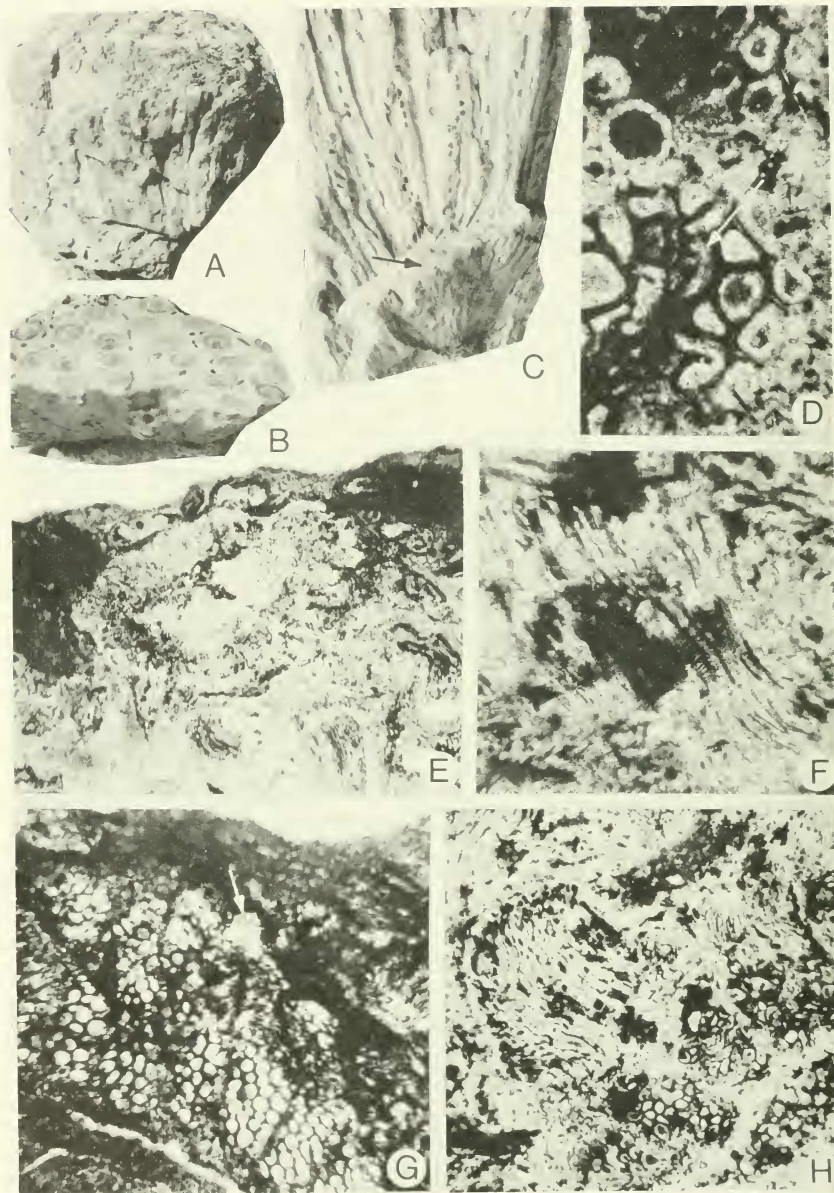
endodermis surrounds them, and crenate sclerenchyma is present in the adaxial concavity of these strands. The inner cortex of the petiole is composed of parenchyma cells 30–60  $\mu\text{m}$  in diameter. The fibers of the sclerotic ring are uniform in size, 30–60  $\mu\text{m}$  across, and continuous with those of the outer cortex.

Stipular wings of the leaf bases are shorter at lower levels, becoming longer at higher levels, and are often distorted by penetrating roots. Wing expansions are from 4 to 17 mm from tip to tip, with the parenchyma cells of the wings being 40–80  $\mu\text{m}$  in width and generally filled with dark contents (Fig. 2C). Epidermal cells are 10  $\mu\text{m}$  wide  $\times$  30–40  $\mu\text{m}$  in tangential length, and cuticle is not preserved. A 3-cell-wide palisade layer having cells 50–100  $\mu\text{m}$  long  $\times$  40  $\mu\text{m}$  wide is present immediately below the abaxial epidermis. One, occasionally two, strands of fibers 40  $\mu\text{m}$  or more across, composed of upwards of 80 cells with each cell being about 10  $\mu\text{m}$  wide, occur approximately one-half the distance between the sclerotic ring and the wing tip (Fig. 1B). Some stipular wings lack these groups of sclerenchyma.

Numerous adventitious roots occur throughout the specimen. They are diarch with the phloem, pericycle and endodermis being crushed. The metaxylem tracheids are 50  $\mu\text{m}$  and the exarch protoxylem tracheal elements 15  $\mu\text{m}$  in diameter. Cells of the parenchymatous inner cortex are 20  $\mu\text{m}$  wide and surrounded by a homogeneous, sclerenchymatous outer cortex. Most of the roots are cut transversely, which suggests an arborescent growth habit (Miller 1971).

**COMPARISON.**—*Aurealcaulis moorei* is proposed as a new species with the following characteristics: an erect to arborescent habit, a heterogeneous pith, nonclosure of its leaf gaps, formation of its C-shaped trace by fusion in its inner cortex of two segments from adjacent xylem strands, 16–22 traces in its cortices, sclerenchymatous outer cortex that connects with the sclerotic ring of the petiolar

Fig. 2 (see facing page). *Aurealcaulis moorei* sp. nov. (all transverse views): A, actual specimen (5041); stem (a) near edge of specimen with petiole bases (b) and roots (c) making up remainder of specimen, X1; B, close-up of a portion of the stem; pith (a), xylem strands (b), inner cortex (c), outer cortex (d), leaf trace (e), oblique section of two segments of a leaf trace, (f) is left side and (g) is right side, which is still attached to xylem strand (h) (5041, 1), X5; C, petiole vascular strands with stipular wings (a) attached; note sclerotic ring (b) surrounding the C-shaped strand (c) (5041, 1), X5; D, two segments of a leaf trace that have not completely fused (5041, 1), X15; E, leaf trace after segments have fused (5041, 1), X10; F, close-up of the xylem strands and the pith (5041, 1), X5.



vascular strand, leaf bases with crenate-shaped sclerenchyma lining the concavity of their vascular strands, and may or may not contain one, occasionally two, cellular masses of sclerenchyma in their stipular wings.

*Aurealcaulis moorei* differs from the other species of *Millerocaulis* and *Osmundacaulis* and from living members of the Osmundaceae (Hewitson 1962) in its manner of trace and root origination, its lack of gap closure, and the exarch protoxylem clusters in its xylem strands.

*Aurealcaulis moorei* can be distinguished from the generitype *A. crossii*, which was reported from the Paleocene Fort Union Formation near Rock Springs, Wyoming (Tidwell and Parker 1987), by its having a heterogeneous pith, fibrous outer cortex, and sclerenchyma in its petiolar strands and stipular wings, all of which are not present in *A. crossii*.

*Aurealcaulis bransonii*, sp. nov.

Figs. 1C-K, 3B-H, 4

**DIAGNOSIS.**—Erect, stem 15–20 mm across, surrounded by leaf bases and roots; stele 7 mm  $\times$  10 mm in diameter, dissected ectophloic siphonostele; pith 3 mm  $\times$  6 mm across, homogeneous, parenchymatous; xylem cylinder dissected, 35–40 xylem strands separated by narrow leaf gaps, strands 17–20 tracheids thick radially and 3–6 metaxylem tracheids wide, gaps generally lack closure, protoxylem exarch; phloem external; inner cortex parenchymatous, narrow, .05 mm wide; outer cortex 10 mm thick, homogeneous, sclerenchymatous; 15–19 leaf traces per cross section of cortices; two segments originating from adjacent xylem strands depart and fuse into C-shaped leaf trace in inner cortex; protoxylem becoming endarch; petiolar vascular strand curved; interrupted sclerenchyma adaxial to strand; sclerotic ring heterogeneous; stipular wings contain 6–8 masses of sclerenchyma aligned from near sclerotic ring to near tip; roots arise from lateral edges of segments of traces before they fuse.

**REPOSITORY.**—Brigham Young University 5042 (HOLOTYPE); 5043, 5044 (PARATYPES).

**LOCALITY.**—Uncertain, possibly the eastern slope of Angel Peak, northwestern New Mexico.

**HORIZON.**—Uncertain, possibly the San Jose Formation.

**AGE.**—Uncertain, possibly Early Eocene.

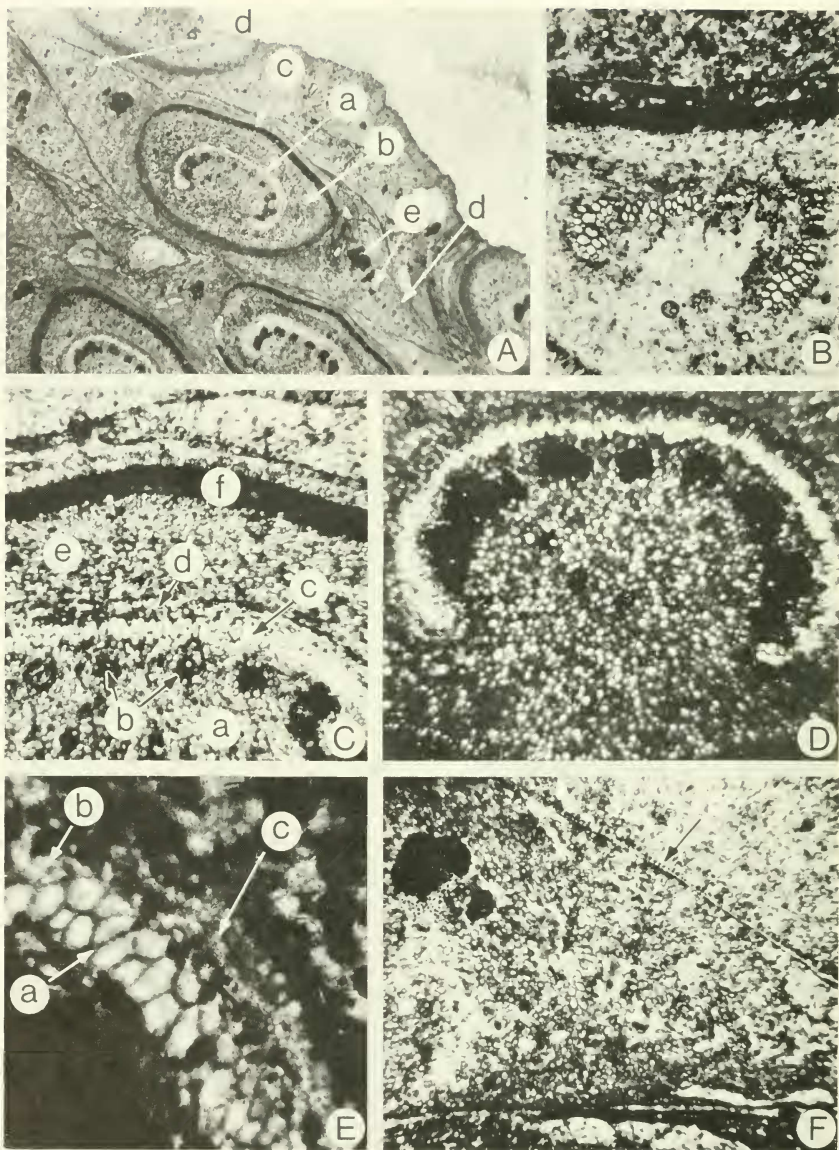
**ETYMOLOGY.**—The specific epithet is for Mr. William Branson of Helper, Utah, for his assistance with this study.

**DESCRIPTION.**—The holotype is 100 mm tall  $\times$  60 mm across, tapered, flattened, and split in half due to weathering (Fig. 3B). Its stem is present for about one-third the vertical distance of the specimen before it disappears because of erosion, and the leaf traces and petiole bases can be observed at various levels of the petioles (Fig. 3C). Roots appear between the petioles in longitudinal sections; whether they continued outwardly into or bent downwardly into the soil cannot be determined. Paratype (BYU 5043) is fairly large, 150 mm  $\times$  250 mm, and without a stem. The specimen is composed primarily of petiole bases, as is the other paratype (BYU 5044). The latter specimen is smaller (25 mm  $\times$  75 mm), but its curvature suggests the original was at least 600 mm in diameter.

The isodiametric parenchyma cells of the pith are 70–150  $\mu$ m in diameter and thin walled. They are filled with dark contents and in some areas are crushed.

The xylem cylinder is 1.5–1.75 mm wide and consists of strands generally separated from one another by the leaf gaps (Figs. 3E, 3G). These strands are only occasionally connected and then by 2–3 tracheids at most. Metaxylem elements in the strands are 70–150  $\mu$ m wide by 270–900  $\mu$ m long with scalariform pitting in their multifaceted walls (Fig. 3F). Many of these tracheids are filled with crystals. Their walls vary in thickness from relatively thin (10  $\mu$ m) to thick (25  $\mu$ m) with wide (50–120  $\mu$ m) to narrow (30–70  $\mu$ m) lumens. Protoxylem elements are also thick walled (Fig. 3D).

Fig. 3 (see facing page). A, Side view of holotype of *Aurealcaulis moorei* sp. nov. (5041), X4; B–H, *Aurealcaulis bransonii* sp. nov. (5042): B, side view of holotype; remains of stem near base (arrow) and roots projecting between petioles, X.75; C, top view of holotype showing transverse sections of petioles; note the stipular wings, X.75; D, close-up of tip of xylem strand illustrating protoxylem cluster (arrow) (5042, 1), X200; E, transverse section of the stem (5042, 1), X7; F, close-up of a longitudinal view of one-half of trace departing xylem strand; note the scalariform thickenings on the tracheid walls (5042, 1), X40; G, close-up of xylem strands; arrow indicates protoxylem cluster (5042, 1), X40; H, close-up of departing trace in longitudinal view (5042, 1), X25.



The phloem is 2–3 cells across and, along with the xylem sheath, pericycle, endodermis, and inner cortex, is poorly preserved. The space originally occupied by the xylem sheath is 20–40  $\mu\text{m}$  wide. It appears to have enclosed the xylem strands and formed the cellular tissue of the gaps.

Formation of the leaf traces and petiole bases is essentially the same as for *A. moorei* (Figs. 3H). The small number of leaf traces (15–19) in transverse section of the cortices and the general nonclosure of the leaf gaps suggest long internodes in this species.

The sclerenchyma in the concavity of the petiolar vascular strand appears at a higher level of the petiole. Initially, it is continuous but eventually becomes interrupted (Figs. 4C, 4D). Two clusters of sclerenchyma fuse together near the tips of the strand, but the remainder remain separate. The fibers of this tissue are angular, thick walled, and 5–12  $\mu\text{m}$  in diameter.

Metaxylem tracheids of the petiolar vascular strands are 30–70  $\mu\text{m}$  across and surrounded by a xylem sheath 1–2 cells wide (Fig. 4E). The phloem is 2–3 cells wide and enclosed by a single-layered pericycle with cells 7–15  $\mu\text{m}$  in diameter and a discontinuous, uniseriate endodermis having cells filled with dark contents. Cells of the inner cortex of the petiole are 20  $\mu\text{m}$  wide and thin walled, with clusters of sclerenchyma occurring irregularly in this tissue (Fig. 4C). Sclerotic rings of the petioles are heterogeneous, with the majority of the cells being thick walled and 30  $\mu\text{m}$  across, whereas the outer, abaxial 12 layers of cells are thinner walled and weather differently from the other cells of the ring. These rows of cells taper to one row on each side of the ring.

The thin-walled parenchyma cells of the stipular wings are 25–30  $\mu\text{m}$  across, and most are filled with contents (Fig. 4F). Cuticle and epidermis of the wings are poorly preserved, with the epidermal cells being 2.5  $\mu\text{m}$  wide. Six to eight masses of sclerenchyma occur in each wing. These masses are aligned from

near the sclerotic wing to the tip. The largest near the ring is 300  $\mu\text{m}$  in diameter, whereas the smallest is 150  $\mu\text{m}$  and near the tip. These masses comprise thick-walled fibrous cells 12–15  $\mu\text{m}$  wide.

The roots of *A. bransonii* are like *A. moorei* and weave their courses between the stipular wings of the petioles. Roots invading the wings are relatively rare.

COMPARISON.—*Aurealcaulis bransonii* has a homogeneous pith and partial closure of its leaf gaps similar to *A. crossii*, but unlike *A. moorei*. *Aurealcaulis bransonii* has a lower trace number in its cortices than the other two, interrupted sclerenchyma in the concavity of its petiolar strand, a heterogeneous sclerotic ring, and 6–8 masses of sclerenchyma in its stipular wings, none of which are present in either *A. crossii* or *A. moorei*.

## DISCUSSION

Because *A. moorei* and *A. bransonii* vary from the genus *Aurealcaulis* as previously defined (Tidwell and Parker 1987), the genus is emended slightly in this report to contain species assignable to this genus, but having such variations as heterogeneous or homogeneous piths, protoxylem becoming endarch in the leaf traces, petiolar vascular strands formed by fusion of segments from the xylem strands in the inner cortex, outer cortex, or outside of the stem, and occurrence or non-occurrence of sclerenchyma in the adaxial concavity of their petiolar vascular strands and in their stipular wings.

The occurrence in *Aurealcaulis* of thin-walled cells in its inner cortex, closely adhering petiole bases, and external phloem and endodermis represents a primitive condition for this genus in the Osmundaceae (Miller 1971). The fact that species of *Aurealcaulis* are exarch and arborescent places them among the more primitive members of the family. Based upon seven primitive to advanced characters proposed by Miller (1971) for this family with an additional one specific to

Fig. 4 (see facing page). *Aurealcaulis bransonii* sp. nov. (all transverse sections): A, leaf base illustrating petiolar vascular strand (a), outer cortex (b), sclerotic ring (c), and stipular wings (d) containing masses of sclerenchyma (e) (5042, 1), X7; B, close-up of petiolar vascular strand after departing from stem (5042, 1), X25; C, close-up of vascularization of a petiole showing inner cortex (a), sclerenchyma in adaxial configuration of strand (b), xylem (c), phloem (d), outer cortex (e), and sclerotic ring (f) (5042, 1), X25; D, same as Fig. 4C showing more inner cortex of petiole, X25; E, enlargement of a portion of Fig. 4C xylem (a), xylem sheath (b), and phloem (c); endodermis and pericycle are poorly preserved, X75; F, stipular wing containing masses of sclerenchyma; note the epidermis (arrow) (5042, 1), X25.

TABLE 1. Comparison of *Aurealcaulis* species.

	<i>A. crossii</i> Tidwell & Parker	<i>A. moorei</i> sp. nov.	<i>A. bransonii</i> sp. nov.
Pith	homogeneous	heterogeneous	homogeneous
Xylem strands	55	32–36	35–40
Number of traces in cortex	28–30	16–22	15–19
Outer cortex	not fibrous	fibrous	fibrous
Sclerenchyma in stipular wings	none	may or may not be present	6–8 aligned masses
Age	Paleocene	Lower Eocene(?)	Lower Eocene(?)

*Aurealcaulis*, *A. bransonii* seems to be the more advanced of these species of *Aurealcaulis* and *A. crossii* the most primitive (Table 1). The general trend of less sclerenchyma in less specialized ferns (Wagner 1964) appears to apply to *Aurealcaulis*. *Aurealcaulis moorei* would be more advanced with its heterogeneous pith, but this is offset by having only an occasional mass of sclerenchyma in its stipular wings and, like *A. crossii*, a homogeneous sclerotic ring. *Aurealcaulis crossii* lacks any sclerenchyma in its wings, a primitive character, whereas *A. bransonii* has 6–8 masses in each wing and is thus more advanced. The inner cortex of the petiole of *A. bransonii* has irregularly shaped clusters of sclerenchyma and a heterogeneous sclerotic ring, both of which are considered advanced characters. These features are lacking in the other two species. Supported by their possible geologic ages, the fusion of the segments in the outer cortex of the older *A. crossii* (Paleocene) may be more primitive than fusion of these segments in the inner cortex of the younger *A. moorei* and *A. bransonii* (possible Eocene). Another probable character is the reduction in the number of strands in the xylem cylinder from 50–60 for *A. crossii* to 32–36 for *A. moorei* and 35–40 for *A. bransonii*.

Among living members of the Osmundaceae, the petioles of *A. bransonii* most closely resemble species of the subgenus *Plenasium*, particularly *Osmunda banksiaefolia* (Hewitson 1962). Distribution of the sclerotic masses in the inner cortices of their petioles and stipular wings is quite similar. The crenate-shaped sclerenchyma lining the adaxial concavity of the strand in *O. banksiaefolia* is like that of *A. moorei* and unlike that of *A. bransonii*, which is interrupted. The xylem cylinders of taxa of the *Plenasium*-type are distinctively different from those of the *Aurealcaulis* species.

The phylogenetic sequence in *Aurealcaulis* is unclear and appears to represent a unique osmundaceous line that became extinct. The ancestor of this genus is unknown. With some modifications, however, earlier members of the *Aurealcaulis* evolutionary line may have arisen from an ancestor common to both them and the subgenus *Plenasium*. It is interesting that a large number of the species of *Millerocaulis* (Tidwell 1986) and most members of *Osmundacaulis* (*sensu stricto*) appear to be related in some way to the subgenus *Plenasium*. Certainly not all members of *Millerocaulis* and *Osmundacaulis* similar to the *Plenasium* subgenus can be its ancestor (Tidwell 1987). However, if the hypothesis of *Aurealcaulis* and *Plenasium* having a common ancestor is correct, then older forms of *Aurealcaulis* should be encountered eventually.

If these species come from the San Jose Formation, then the environment of the Angel Peak area where *A. moorei* and *A. bransonii* may have occurred can be determined by the associated impression-compression flora (Tidwell et al. 1981), as well as these osmundaceous species. Modern relatives of the flora from Santos Peak occur in moist environments, and living members of the Osmundaceae grow in tropical to cool temperate climates and can be found in bogs, swamps, rain forests, and damp woodlands (Gould 1981). An axis of *A. crossii* was collected in growth position in a lignitic bed of the Fort Union Formation, indicating that this species had grown in swamps. Furthermore, the area in which *A. crossii* occurred seems to have been a forest that grew under swampy conditions on a flat flood plain in a subtropical to warm temperate climate (Brown 1962, Roehler 1979). *Aurealcaulis moorei* and *A. bransonii* very likely grew under similar conditions. It can be concluded, therefore, that the San Juan Basin was, in general, a humid, forested region during the time these plants grew.

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